Advanced inertial sensors for fundamental physics and gravitational wave astrophysics

Completed Technology Project (2015 - 2017)

Project Introduction

Gravitational wave detection is one of the most compelling areas of observational astrophysics today. It represents an entirely new way of observing our universe and therefore provides enormous potential for scientific discovery. Low frequency gravitational waves in the 0.1 mHz to 1 Hz band, which can only be observed from space, provide the richest science and complement high frequency observatories on the ground such as LIGO. A space-based observatory will improve our understanding of the formation and growth of massive black holes, create a census of compact binary systems in the Milky Way, test general relativity in extreme conditions, and enable searches for new physics. All space-based gravitational wave observatories, like the Laser Interferometer Space Antenna (LISA), require free falling masses where all classical external forces are reduced below the tidal forces of the oscillating spacetime metric. No other concept has been found that would allow gravitational waves to be measured in the LISA frequency band. LISA Pathfinder (LPF), an ESA technology mission, will test key technologies for LISA and is scheduled for launch in July of 2015. However, the design of the LPF inertial sensor was solidified a decade ago. Since that time, new component technologies have been developed that can improve the sensor's acceleration noise performance and/or reduce complexity and technological risk. They are (a) alternate test mass and electrode housing coatings that can greatly simplify the caging system, (b) a new, lower cost and higher efficiency charge control system utilizing semiconductor UV emitters instead of Hg vapor lamps, and (c) operational modes of the inertial sensor that can mitigate the effects of higher than expected noise in the driving electronics and potential on-orbit thruster failures. These technologies involve three components of the LPF inertial sensor that represented the biggest technical challenges for the mission and were responsible, in part, for the delayed launch date. Evolved LISA, or eLISA, the European-led gravitational wave observatory, was recently selected as ESA's L3 large mission, with a launch in the 2030s. ESA will allow a 20% NASA contribution to eLISA and NASA has expressed strong interest to participate. Some of the technologies proposed here have already been identified as potential NASA contributions to eLISA by the European eLISA Consortium and by NASA itself. On the other hand, the imminent direct detection of gravitational waves by Advanced LIGO and by Pulsar Timing Arrays will ignite the era of gravitational wave observation. The distant launch data of eLISA, following two other large missions, L1 and L2, which could further delay L3, means that LISA has to be seen as one of the favorites for the next decadal survey. If this is the case, then NASA will not want to completely depend on a single, foreign vendor for the mission-critical inertial sensor, and instead will want to develop U.S. expertise and a U.S. vendor base for this technology to reduce programmatic risks. This Concept Study provides an excellent opportunity for NASA to examine how new ideas and technologies can be integrated into an advanced inertial sensor for gravitational wave astrophysics. During the Concept Study a modified inertial sensor, incorporating these technologies will be designed and undergo initial

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Organizational Responsibility

Responsible Mission Directorate:

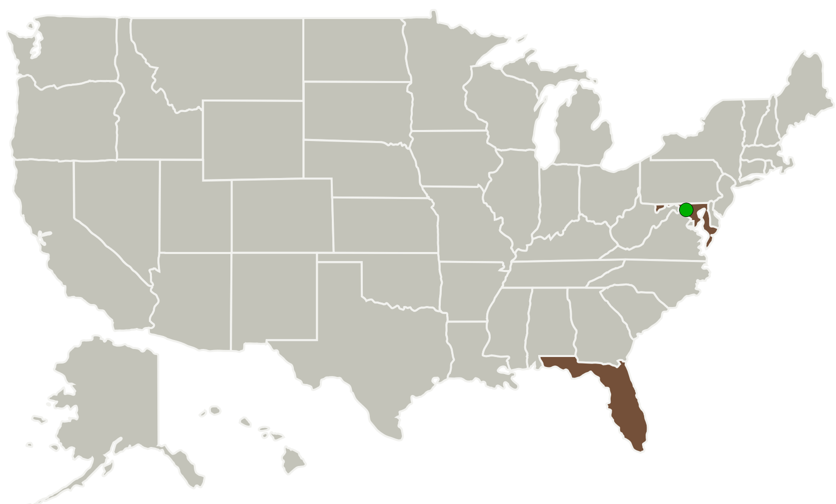
Science Mission Directorate (SMD)

Responsible Program:

Nancy Grace Roman Technology Fellowship

proof-of-concept testing in an existing torsion pendulum facility at the University of Florida. The subsequent Development Effort will first optimize the sensor design, taking advantage of lessons learned during the laboratory testing and possibly from the on-orbit performance of LISA Pathfinder. Then a prototype instrument will be fabricated and prepared for more rigorous testing on ground and on sub-orbital flights and/or on the International Space Station.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Division of Sponsored Research - University of Florida	Supporting Organization	Academia	St Augustine, Florida
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations	
Florida	Maryland

Project Management

Program Director:

Mario R Perez

Program Manager:

Mario R Perez

Principal Investigator:

John W Conklin

Co-Investigators:

Roslyn S Heath
James I Thorpe

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.1 Detectors and Focal Planes

Target Destination

Outside the Solar System